REPORT DOCUMENTATION PAGE	Form Approved OMB NO. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
02-07-2014	Final Report	15-Jun-2012 - 14-Mar-2013

4. TITLE AND SUBTITLE
Exercise-induced Alteration in Brain Activity during Motor Performance under Cognitive Stress

5a. CONTRACT NUMBER
W911NF-12-1-0249

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
611102

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSOR/MONITOR'S ACRONYM(S)
ARO

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
62146-LS-II.1

12. DISTRIBUTION AVAILIBILITY STATEMENT
Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES
The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT
The specific aim of the study was to examine the potential changes in the beta-band (15-30 Hz) neural oscillations between brain and muscle during simple fine motor performance under stress after high-intensity physical exertion. Healthy young adults were assigned to the Experimental or Control groups. Steady low-level force matching task using the index finger was performed independently (Single task) and concurrently with a cognitive task (Dual task) for 3 time blocks. Between the 1st and 2nd time blocks, subjects in the Experimental group performed active

15. SUBJECT TERMS
Brain activity, neural oscillations, exercise, stress

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
UU	UU	UU	UU		Minoru Shinohara
					19b. TELEPHONE NUMBER
					404-894-1030

Report Title

Exercise-induced Alteration in Brain Activity during Motor Performance under Cognitive Stress

ABSTRACT

The specific aim of the study was to examine the potential changes in the beta-band (15-30 Hz) neural oscillations between brain and muscle during simple fine motor performance under stress after high-intensity physical exertion. Healthy young adults were assigned to the Experimental or Control groups. Steady low-level force matching task using the index finger was performed independently (Single task) and concurrently with a cognitive task (Dual task) for 3 time blocks. Between the 1st and 2nd time blocks, subjects in the Experimental group performed active leg resistance exercise. Oscillations in EEG and corticomuscular coherence in beta band both tended to decrease during the Dual task after resistance exercise. This observation suggested a possible role of resistance exercise for potentially reducing beta-band neural oscillations during fine motor task under cognitive stress. There was a significant negative correlation between peak beta-band corticomuscular coherence and the coefficient of variation of EMG during the Dual task. Collectively, these results implied that reduction in beta-band corticomuscular coherence due to high-intensity physical exertion may lead to increased variability in motor output under cognitive stress.

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Statement of the problem studied

Many battlefield operations involve the combination of motor task and cognitive task during and after physical exertion. In particular, fine motor task is often degraded with concurrent cognitive task (Johnson & Shinohara 2012). Better understanding of neural activity in such a demanding situation would help assess the neural state that would be related to the task capability of warfighters at the battlefield. The ultimate goal of the project is to understand the effect of physical exertion and cognitive stress on neural mechanisms for motor performance.

Motor tasks involve the activation of muscle by the brain. Electrical activity of the brain and muscle may be obtained as an electroencephalogram (EEG) from the motor cortex and as an electromyogram (EMG) from the activated muscle, respectively. EEG electrodes on the scalp measure activity from a large number of neurons in underlying regions of the brain. Each neuron generates a small electrical field that changes over time. The source of current causing the fluctuating scalp potential is primarily the pyramidal neurons and their synaptic connections to deeper layers of the cortex. The oscillations are a result of the reciprocal interaction of excitatory and inhibitory neurons in circuit loops.

Oscillatory electrical activity in the brain (EEG) is often altered after exercise in terms of their frequency and magnitude (Crabbe & Dishman 2004). However, the role of this exercise-induced alteration in EEG profile for subsequent motor performance was unclear. Beta-band corticomuscular coherence (i.e. correlated oscillations) between EEG in the primary motor cortex and a contracting hand muscle (EMG) appears to be associated with the performance of fine motor task (Kristeva et al. 2007; Lundbye-Jensen & Nielsen 2008). Changes in beta-band EEG power are more often observed at higher exercise intensities (Mierau et al. 2009; Schneider et al. 2009). The purpose of the current study was to examine the potential changes in the beta-band (15-30 Hz) neural oscillations between brain and muscle during fine motor performance under cognitive stress after high-intensity physical exertion.

Summary of the most important results

Healthy young adults were recruited and assigned to Experimental (n = 11, 5 woman, 24 ± 4.3 years old) or Control (n = 8, 1 woman, 24 ± 7.3 years old) groups. Steady low-level force

matching task using the index finger was performed independently (Single task) and concurrently with a cognitive task (Dual task) for 3 time blocks. Between the 1st and 2nd time blocks, subjects in Experimental group performed leg resistance exercise. Corticomuscular coherence between EEG and EMG of the hand muscle was obtained according to previous studies (Halliday et al. 1995; Johnson & Shinohara 2012; Rosenberg et al. 1989).

Perceived exertion and physiological stress was greater during Dual task compared with the Single task. Exercise also increased physiological stress. The magnitude of beta-band oscillations in cortical activity tended to decrease with time during Dual task in Experimental group. In contrast, the magnitude of beta-band corticomuscular coherence tended to increase with time in both tasks in Control group. There was a significant negative correlation between the magnitude of beta-band coherence and the variability of motor output (coefficient of variation of EMG) in the 2^{nd} time block.

The tendency for reductions in beta-band oscillations in EEG and corticomuscular coherence during Dual task after resistance exercise is in line with the decline in beta-band EEG power after exercise in the literature (Mierau et al. 2009; Schneider et al. 2009). The tendency implies a possible role of resistance exercise for potentially reducing beta-band neural oscillations during fine motor task under cognitive stress. The negative correlation between the magnitude of beta-band coherence and the variability of motor output indicates that individuals with greater beta-band corticomuscular coherence show less variability in EMG when maintaining low-level finger force under cognitive stress. Since less variable EMG leads to less variable muscle force, the observed correlation suggests potential role of beta-band neural oscillations in reducing variability in motor output. Hence, the results imply that reduction in beta-band corticomuscular coherence due high-intensity physical exertion may lead to increased variability in motor output under cognitive stress. It is possible that the correlated activity between EEG and EMG is used for “fine-tuning” brain activity during the performance of fine motor task under cognitive stress. In this regard, the current findings serve the basis for the future applicability of assessing neural oscillations for objectively and quantitatively assessing the capability of individual war-fighters for fine-tuning their brain activity for fine motor skills under cognitive stress with physiologically demanding operations.

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Appendixes

None.